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TWO LECTURES

ON

IMPURE AIR AND VENTILATION.

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AN ABSTRACT OF LECTURES DELIVERED BEFORE THE CLASS.

LECTURE I. THE PRINCIPAL IMPURITIES OF RESPIRED AIR.

LECTURE II. THE PRINCIPLES OF VENTILATION OF DWELLING HOUSES.

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ON IMPURE AIR AND VENTILATION.

LECTURE I.

THE PRINCIPAL IMPURITIES OF RESPIRED AIR.

CHEMICAL CHANGES IN AIR; ITS VITIATION.—This subject demands a fuller study than is usually given to it in the text-books. Its consideration will, for the present, be confined to the case of inhabited houses, excluding, as a rule, open-air sources of vitiation, as malaria, etc.

We may divide the subject as follows:—

1. Ordinary vitiation. (*a*) Diminution of oxygen. (*b*) Increase of carbonic acid CO_2 [HCO_3].* (*c*) Increase of ammonia NH_3. (*d*) Increase of organic matter as albuminoid principles and fat-acids.

2. Extraordinary or introduced injurious bodies. (*a*) Carbonic oxide CO. (*b*) Acetylene and illuminating gas, sulphuretted hydrogen HS [H_2S], perfumes, and dampness. (*c*) Sewer and ground gas. (*d*) Dust.

3. Special injurious bodies, such as are due to certain manufactures.

(1) *Ordinary Vitiation.*—(*a*) Diminution of oxygen. The loss of oxygen by respiration and ordinary combustion of gas, candles, etc., is comparatively small. Taking the normal quantity as 21 per cent. by volume, the lowest in Angus Smith's table is (in the gallery of a theatre) 20.36. In mines, the average of eighteen samples was 17.067, and, in one case, as low as 14.51. The explosion of blasting-powder would, in part, account for these low figures (Heywood). An atmosphere containing only 11 per cent. will not support life.

(*b*) Increase of carbonic acid. This is much more marked, and varies within wide limits. A few examples will show this.† The normal proportion of carbonic acid by volume is taken as 4 in 10,000.

Hot-house, morning, parts in 10,000,	Leblanc,	0.65
Hot-house, evening,	"	0.00
Lecture room, Sorbonne, after lecture,	"	67.36
Opera Comique (parterre), ventilated,	"	3.76
Opera Comique (ceiling), "	"	7.03
External air, Munich,	Pettenkoffer,	4.52
Well-filled school-room, Munich,	"	72.00
Public school, Washington,	Wetherill,	17.18
Bed-room, after rising,	"	8.00
Houses of Congress (mean), ventilated,	"	6.4

* The symbols in brackets are molecular, or unitary (so called).

† Wetherill's Report on Warming and Ventilating the Capitol to 39th Congress, 1866.

Even when there is no visible ventilation, a large amount of carbonic acid escapes through walls and cracks. This will be more fully considered hereafter.

An ordinary (5 ft.) gas burner consumes oxygen and gives off CO_2, about equal to the respiration of four adult persons.

Carbonic acid does *not* accumulate near the floor, as is so often stated and so generally believed; but, being warmed at the time of its formation, rises and is found in greater proportion near the ceiling. By the law of diffusion of gases it, in time, becomes equally mingled throughout the air, and will not again separate.

Contrary to general opinion and the statements in crude books, carbonic acid is *not* poisonous. Like nitrogen, when breathed in large quantity, mixed with oxygen or air (one-half or more of the volume of the latter), it produces symptoms, due to want of sufficient oxygen, which are transient. It cannot, any more than any other inert gas, be breathed alone. As to its effect, if in excess in ordinary air, when habitually breathed, and unaccompanied by other products of respiration and ex. halation, we have no data on which to found an opinion.

While the increased carbonic acid found in close rooms cannot be blamed as causing the immediate ill effects, as headache, drowsiness, etc., yet it is valuable as an index of the amount of organic matter present from the expired air so manifest to the smell. It is not an exact index, as CO_2 from gas burners, etc., is not accompanied by organic matter; these burners also destroy a portion of it.

(*c*) Ammonia is found in larger proportion in inhabited rooms than in the open air, probably as carbonate. It can be detected by Nessler's test in the washings of furniture, windows, etc. It is also valuable as a comparative indicator of the quantity of organic matter (Angus Smith). In the celebrated case of the black-hole of Calcutta,* the narrator compares the sensation towards the last, "as if we were forcibly held with the head over a bowl of strong volatile spirits of hartshorn." In the quantity found in ordinary cases it cannot *per se* be considered injurious.

(*d*) Organic matter. This is doubtless the

* See the full narrative by Mr. Hollwell in Chandos' edition of Percy's Anecdotes, vol. i. p. 397.

great source of the injury caused by ill-ventilated and dirty rooms. It varies in its nature as the individuals giving it off vary; and, in the same individual, as much as the other secretions and excretions. It is remarkable that crowded and dirty rooms should have a similar repulsive smell, yet such is the case. This smell differs somewhat in a crowded room from one that has been emptied, but cannot be mistaken. It is even noticeable in the clothing, etc., of persons coming out of such an assembly, and is familiar to the practitioner of medicine in the sick-room. Certain diseases, as smallpox, measles, scarlet fever, dysentery, rheumatism, typhus and typhoid fevers have peculiar and offensive emanations. The quantity of vapour given off by the human adult body from the skin and lungs may be stated at about three pounds a day. This varies with the individual, and in the same person with the temperature, amount of exercise, food, drink, etc. The smell of the perspiration, sensible and insensible, is due to volatile fatty acids (acetic, capric, caproic, and caprylic), and varies with the individual, race, ingesta, part of the body, etc.

The following table is from observations of Dr. Angus Smith, who used a standard solution of permanganate of potassa, KO,Mn_2O_7 [$K_2Mn_2O_8$] (potassium permanganate), through which the air was drawn, care being taken to exclude other decolourizing agents. The ratio of the quantity of air required to decolourize the potassium permanganate was as follows:—

High ground of Lancashire . . .	22
Open street in Manchester . . .	9
Small houses on the medlock . . .	5.5
Closely packed railway car . . .	2

The relative quantity of ammonia as an indicator of the presence of organic matter is not as yet satisfactorily determined. While the sense of smell generally warns us of the presence of organic matter, some aërial poisons are inodorous.

(2) *Introduced Injurious Bodies.*—These are more or less accidental.

(*a*) Carbonic oxide, CO, is formed by imperfect combustion of solid carbon or its gaseous compounds. It escapes through the pores of cast-iron stoves, more freely when they are highly heated, cracks and bad joints in stoves and pipes, open fires and braziers, and from imperfect gas burners. It is highly poisonous, acting as a narcotic, and causing changes in the blood; by acting on the red corpuscles, expelling oxygen, and replacing it. (Bernard.) The inspiration of not more than a single cubic inch of CO has caused insensibility. Long breathed, when diluted, it causes nausea, vertigo, and convulsions. (Nicolle.) As it has neither colour nor smell its presence easily escapes detection, and persons who die from its immediate effect are unconscious of their danger and make no effort to escape.

Acetylene, C_4H_2 [C_2H_2] is, like carbonic oxide, formed during the imperfect combustion of moist coal or the hydrocarbons. It is especially noticed in faulty gas burners and gas stoves. It is colourless, has a peculiar odour, and produces headache and nausea. No observed cases of its other ill effects have been noticed.

(*b*) Illuminating gas is a complex mixture of compounds of carbon and hydrogen, carbonic oxide, carbonic acid, ammonia, and nitrogen. It has caused death, as in cases of workmen going into partially emptied gas holders, and persons blowing out the gas before going to bed. From bad plumbing it often escapes in buildings. No account of its effects as a slow poison are known. Workmen employed about its manufacture are generally healthy. In 1849 they enjoyed a remarkable exemption from cholera in Philadelphia. Its smell soon calls attention to its escape, and its explosion when mixed with air has caused many accidents. It is especially poisonous to plants.

Sulphurous acid, *sulphur dioxide*, SO_2, and sulphuretted hydrogen, HS [H_2S], are given off from gas burners, and especially from damp coal thrown on open fires. When the air is moist the former yields sulphuric acid, HO,SO_3 [H_2SO_4]. These products are probably more harmful by corroding and bleaching furniture and masonry, and blacking silver than by direct injury to health. All are poisonous in quantity, but not especially so when diluted. Sulphuric acid is not volatile, but is carried along with the vapour of water. A small portion of ammonia may escape combustion in gas burners.

Perfumes affect many persons injuriously, especially such as musk and the stronger smelling flowers as the tuberose. Plants when not in flower cannot be considered hurtful in rooms; in sunlight they give off oxygen, the green is grateful to the eye, while the small amount of CO_2 given off during darkness cannot do harm.

Dampness promotes the spread of organic matter, as is shown by the smell of flowers in a garden in the morning and evening or after a shower compared with the dry air of midday. Dirty gutters and cellars are more noisome on a damp day. Excessive dryness is injurious. This part of the subject will be discussed hereafter under *ventilation.*

(*c*) Sewer and ground gas. In large towns many houses are underdrained; that is, all the waste water and excreta pass by pipes into sewers. This avoids the unsightliness of surface drainage, the annoyance from ice, and the necessity of cleaning privy wells. In some

places it is made compulsory by law. The sewers are generally made of porous bricks, badly put together, and covered out of sight as soon as possible. Their wretched construction is manifest from their frequent "caving in." As long as the drainage is visible on the surface or in the well, it can be kept under control by simple measures of cleanliness, although the underground drainage is to be preferred *when properly done.* The matters passing into the sewer form a mass of filth liable to putrefy, giving off carbonic acid, sulphuretted hydrogen, and various unknown, sometimes inodorous, gases, which are known to be poisonous, probably producing diphtheria, typhoid fever, and other low forms of disease. The pipes leading to the sewer are trapped before reaching it, to prevent the passage of these gases back from the sewer. If a trap is not put to each basin near its discharge opening, the whole pipe becomes a small sewer giving off its injurious gases. During heavy rains the street sewers being too small to carry off the water fast enough, the gas is forced backwards through the trap and enters the house. The remedy consists in properly arranged ventilating pipes, better to the main sewer, but as that is seldom done, to the house pipes. These should be carried above the roof of the house or passed into a chimney, care being taken that the joints are tight.*

Cellar gas. Considering that so many houses are warmed by heaters in the cellar, which are not often, as they should be, supplied with clean air from out of doors, this part of the subject becomes important. In any case, the air from the cellar passes up into the house through cracks in the flooring, and occasionally opened doors. With a foul cellar, clean up-stair rooms avail little. Apart from refuse matter allowed to accumulate in the cellar and rot, the ground itself gives off noxious gases. Soils are porous, although in varying degree; sewers and gas mains leak, and so do porous or cracked well walls. Hence, drinking water, in pump or draw wells, is contaminated, and the gaseous matters, working through the soil, pass out into the cellar, thence up into the house.

The prevention is simple; the earth should be floored over with *glazed* brick, slate, or other impervious material; ordinary brick, cement, sandstone, and mortar, are pervious, unless coated with asphalt, or other non-porous material. Air should be admitted freely; cleanliness thoroughly observed, and plain whitewash often used. The lime acts by absorbing organic matter, and, by its caustic nature, destroying it. The dampness of upper rooms often is caused by water rising by capillary attraction from the foundation. An impervious layer of slate, etc., between the foundation and brickwork prevents this. It is often detected too late for remedy.

(*d*) Dust is found suspended in the air of rooms coming from out of doors, or the clothing or bodies of the inmates. It is of course most varying in composition. That of streets contains particles of stone, iron from horseshoes, tires of wheels and car tracks, albuminous matter from hoofs, leather dust, and other organic particles from excreta of animals. In a quiet room, the heavier portions settle, only to be stirred up by the feet or sweeping brush. The part which does not readily settle, is composed of organic matter (wholly, according to Tyndall) and ammonia compounds (carbonate, sulphate, nitrate, and phosphate). It disappears when the air is passed through a red-hot tube, or a flame (Tyndall). The inorganic dust—as it generally occurs—cannot be considered as injurious, since it is constantly present in the open air. By breathing wholly through the nose it is intercepted, and does not reach the lungs. Persons who are obliged to breathe an atmosphere loaded with dust (cutlery grinders, stone-dressers, for example), die early from the effects of the solid matter accumulating in the lungs. The organic matter of dust is accompanied with gaseous products of decomposition. Much of it eludes, not only the senses, but the microscope and chemical tests. There have been found in hospital dust and washings of walls, pus globules, filaments of lint with organic corpuscles, and epithelial scales; the washings soon putrefy, the liquid showing under the microscope low forms of life (vibrios, bacteria). Even ordinary town air will cause rapid fermentation and putrefaction, when allowed access to suitable solutions (sugar) or infusions (hay, meat). In these infusions, the low organisms are detected readily by the microscope, while their germs are beyond the reach of our senses, aided or unaided. That organic matter—recognizable or not—does originate and promote the spread of disease, acute and chronic, is undisputed; but there is much in this study of which we are profoundly ignorant. Whether

* The subject of proper drainage is too extensive to be considered here. Unfortunately, so much is badly done that it is a question, whether on the average the risk to the inmates of an underdrained house is not greater than that of the old system of surface drainage and privy wells. In the country the latter may contaminate the well for drinking water, and doubtless often thus contribute to the spread of disease, especially of typhoid fever and choleraic diseases. In cities, where the water is supplied by pipes, this objection to the use of privy wells does not hold. In Philadelphia there are but 33,100 water closets to 150,000 houses, some houses having three or more. It is estimated that 500,000 of its inhabitants use privy wells, and not the sewer drainage. (Hering, Proceedings Engineers' Club, 5th June, 1880.)

we adopt the glandular theory, which attributes the spread of disease to direct contact of the poisonous matter, or that of unknown germs, which develop in a suitable fluid, matters not. Both views are probably correct in certain cases. We need deal only with facts. The great fact is that *re-breathed air is poison*. *Cleanliness* of air (ventilation), of person, and of habitations, is the great agent in the prevention of disease.

(3) *Special Injurious Bodies.*—These, as vapor of phosphorus in match manufacture, bisulphide of carbon in that of india-rubber, dust of lead and its compounds, etc., can be considered by studying the special elements and compounds involved.

LECTURE II.

THE PRINCIPLES OF VENTILATION OF DWELLING HOUSES.

VENTILATION.—The study of the subject of the removal of vitiated air and replacing it by that which is fresh, the proper regulation of the temperature and moisture, with the avoidance of draughts, is a difficult one. In any case much must be left to the judgment and scientific knowledge of the adviser. The consideration of the general principles concerning the problem and some special applications to dwellings can only be considered here. The student is referred to the systematic works on hygiene for a full discussion of this complicated and by no means fully understood subject.

The general neglect of ventilation in theatres, school-houses, churches, and dwellings is too manifest to need comment. This is due partly to ignorance, carelessness, or false economy on the part of builders, to the desire by the residents to save fuel (as the foul air to be drawn off is warm), and to personal neglect. In winter houses are kept closed, clothing is less often changed than in summer, bathing less frequently resorted to, thus allowing impurities to accumulate.

The increase of the so-called zymotic diseases during the winter season, as shown by the published list of deaths, speaks for itself.

The products of respiration and combustion and the emanations from the surface of the body will on account of their higher temperature, if not interfered with, rise and find egress from any openings at or near the top of the room. Once in the outer air they are diffused and rendered harmless by natural agencies, notably by that of vegetation.

A large amount of ventilation goes on through walls, ceilings, and crevices. This form of generally overlooked interchange of the outer and inner air has been inaptly termed "natural ventilation." Nature is governed by unchangeable laws, which, as will be seen, is not the case in this instance, because of artificial impediments to them.

This part of the subject may be considered under two heads: (1) Transmission through building materials; (2) through cracks and crevices.

(1) Building materials vary greatly in their permeability by air and gases. Bricks and earthenware when glazed or vitrified, slate, and rolled metal are impervious to air and moisture. Sandstones, limestones, unglazed baked clay, mortar, and cements *when dry* are more pervious than is generally supposed. By cementing two tubes to opposite sides of a small slab and coating it with varnish, except where the tubes are attached, a candle may be blown out by the breath; or by passing coal gas into the under tube it will pass through the slab and burn at the mouth of that on the upper side.* Wood has a high transmitting capacity, which varies with its density, pine being much more porous to gases than oak.

The rapidity of transmission with the same material diminishes with the thickness and increases with the pressure on the exposed side. This varies with the velocity of the wind. A moderate breeze, having a velocity of eight miles per hour, blowing at right angles to the wall, will exert a pressure of about one-third of a pound on each square foot. A high wind of thirty miles per hour will give a corresponding pressure of four pounds and a half. The amount of air passing through a dry naked brick wall one foot thick in the latter case may amount to one hundred times the volume in the same time as in the former, and will reach twenty cubic feet per hour for a surface of twenty-five square yards. Wetting stops the transmission, and it is prevented or diminished by painting, papering, metal sheathing, etc. The inner air differs so little from that outside, in its strictly gaseous composition, that on a damp day there is little or no diffusion through the walls, except that due to the difference of temperature, which may, in practice, be neglected.

(2) Cracks and crevices. Even in well-built houses the effect of the shrinkage of woodwork

* This is well shown by Graham's diffusion tubes. A porous cup of unglazed clay (such as is used in Grove's or Daniell's cells) is cemented to the upper end of a glass tube. When the tube is filled with hydrogen and its lower end dipped into water, the latter rapidly rises, because the hydrogen passes out through the porous clay nearly four times as fast as the air can pass in. Conversely, when a bell jar filled with hydrogen is passed over the cup, the tube being filled with air, the hydrogen rushing in causes bubbles of air to escape through the liquid.

is soon seen; window sashes rattle, doors are out of line, and daylight can be seen between them and their frames, while the currents of air are easily noticed. These troubles are partially remedied by wedging the window sashes against their frames from the inside, the use of sand bags and weather strips *

Draughts.—Persons exposed to out-door inclemency, as sailors, soldiers on the march, engineers, and sportsmen, seldom take cold. The only precaution seems to be to avoid sitting or lying on the bare ground, or checking sweating by rapidly cooling off after violent exercise. It is when a portion only of the body is chilled that there is the most risk. A man will escape harm from a ducking, but be made sick from wet feet. The inmates of houses are exposed to draughts, not only through cracks and key-holes, but from downward currents of cold air from within, due to the cooling effects of walls and windows. (1) Walls.—The passage of the outer air through walls has just been spoken of, and it need only be said that independent of this, the building material possesses a high radiating power, and the heat conducted through the wall rapidly passes into the outer space. A glance at a painted wall in a crowded church or lecture-room will show it to be coated with condensed moisture. The paint may be impervious, but does not prevent the cooling by conduction and radiation. Air cooled by contact with the wall falls, making a draught even in a close room. (2) Still more marked is this the case with glass. A window, as tight as art can make it, is cold to the touch in wintry weather, and soon is coated with moisture or frost. Although glass is impervious to air, yet its radiating power is high (90 on Melloni's scale, the highest being 100), and from the thinness of the plates in windows it conducts rapidly. The outer surface is rapidly cooled by radiation and by contact of the outer cold air, and the inner surface soon acquires and maintains nearly the same temperature. Hence persons sitting by a closed window are exposed to downward draughts, even when the window is made as nearly as possible air-tight.†

The most simple method of ventilation is to allow the heated vitiated air to escape by openings near or in the ceiling, while fresh air is admitted below (upward system). The cooling effect of walls and windows, just described, interferes seriously with this plan; the foul air coming in contact with these cold surfaces falls to be still more vitiated. A popular error is to confound cool air with fresh air. Unless the air is admitted by numerous openings it is not supplied to all parts of the room, and especially stagnates in the corners. When large openings of egress are used, there is danger of downward draughts. The *downward system* is much employed in large buildings. The fresh air is admitted at or near the ceiling by numerous openings, and drawn off in the same way near the floor, the necessary draught being obtained by a chimney stack, in which is a fire, steam jet, or exhausting fan. This method has given great satisfaction, and is now largely adopted in hospitals. The emanations from each individual may be removed without having opportunity to mingle with the general air of the room.*

In dwelling houses systematic ventilation is rarely found. A window lowered from the top, or a door ajar with a chain bolt, are the commonest methods. Sometimes ventilating registers furnished with a valve to prevent back draughts and opened and closed by a cord are fitted into the chimney. They are useful, but being usually placed over the hot air register draw off the admitted air without giving it a

* In a moderately well-built house, about twenty-five years old, the combined area of the cracks in a single room, with three windows and two doors, was found to be equal to a single opening of nearly one square foot of area. In a badly built house in an exposed situation the inflow through cracks was sufficient to prevent the warm air, from the heater in the cellar, from rising through the register until the draught was checked by the use of sand bags on the windward side of the house. B. H. R.

† One square foot of glass surface will cool over one cubic foot of air per minute from the temperature of the inner to that of the outer air. A single glass window, 6 by 3 feet (supposed to be air tight), will thus cool by contact 108 cubic feet per minute, when the outer air is at 0° the inner at 60°; a dead loss of fuel. This, if saved, would suffice to warm fresh air more than sufficient for ten persons, or to enable the windows of the room to be thrown wide open for fifteen minutes or half an hour. This is the best practical ventilation for a bedroom or sitting-room. It should be done while the room is not occupied, unless in the judgment of the medical attendant a patient may be safely left, if well covered up. The remedy is to be found in hollow walls and double sashed windows. When double sashes are too costly double panes with an air space between are useful. When transparency is not essential, a tight fitting frame over which is stretched some translucent material, as oiled silk or waxed paper, does good service.

* The American Academy of Music is an example of a nearly perfect system of upward ventilation. The auditorium is separated from the outside walls by an inside lobby, so that there are no down currents of cooled foul air; each separate gas burner beneath the tier of seats, in all 205, has a ventilating register. A chandelier of 200 burners occupies the centre of the dome, over which is a large opening of exit. The draught of escaping heated air is powerful but not perceptible to the audience. Fresh air is supplied by grated openings in the floor, and a forcing fan, 10 feet in diameter, 120 revolutions a minute, is used at each performance. The seating capacity is 3000, and when crowded there is no offensive smell in the highest gallery, although the heat radiated from the chandelier is unpleasant.

chance to diffuse. With a door ajar the heated air passes out at the top, the outer air enters near the floor. The result is apt to be unpleasant and hurtful draughts. With a window lowered at the top some fresh air enters at the lower edge of the opening, while the heated atmosphere escapes at the upper; some air also comes in by the space between the lower or fixed sash and the upper (lowered) frame. The sash blind being lowered, draughts are thereby mitigated. In any case where possible the ventilation should be in a communicating adjoining room, which will avoid the draught.

A simple and satisfactory contrivance is a board as long as the window is wide, and about eight inches broad, perforated with numerous half-inch holes. The lower sash is raised and the board placed under it. The upper sash is not moved. The air enters through the holes, and the warmer air escapes by the space between the outer (upper) sash and the inner (lower) one. To avoid draughts a curtain should be tacked to the upper edge of the board, or, better still, the holes covered with wire gauze or perforated metal. Another plan has two large (5 inch) holes in the board fitted with sheet metal tubes curving upwards, and furnished with dampers to regulate the flow of air. This form is patented. It is not recommended. The large pipes make draughts, and persons near their openings will close the dampers and defeat the object of the contrivance.

Open fire-places are admirable ventilators of rooms, but somewhat wasteful of fuel. Wood fires are much more grateful to the occupants, sick or well, than those of coal. Closed stoves (gas consumers, base burners) are convenient and economical, but afford little ventilation, except when the door is left open. The smell of freshly added coal, especially when damp, and the risk of the escape of carbonic oxide and other noxious gases through the stove itself, the joints of the pipe, or by reason of a closed damper, are also objections.

The open Franklin stove, burning either coal or wood, unites the economy of the stove with the cheerfulness and ventilating power of the open fire. It is especially to be recommended for the sick-room. Open fires increase the inflow of air through cracks and other openings.

Temperature.—The proper temperature at which a room should be kept to promote health and comfort depends upon circumstances. Some persons will in a well-ventilated room at 65° complain of chilliness, others of oppressive heat. After a meal some are chilly, others flushed. Hence, in a mixed assembly, there is always complaint. After the large sums spent in the ventilation of the English Houses of Parliament and the Capitol at Washington, it has in neither case given satisfaction. In a quiet sitting-room 65°–70° is generally agreeable. In sleeping-rooms, the occupants being well covered, a lower temperature is better. A high temperature causes restlessness, perspiration, thirst, and a tired feeling on getting up. Hence, even in winter, the window farthest from the bed should be lowered from the top. A well-kept bedroom is as free from closeness in the morning as any other part of the house. Even a sick-room may, with care, be kept entirely free from offensive odor.

Moisture.—The amount of moisture in the air varies with the temperature. It is *not* dissolved, in the ordinary sense of the word. The same space, at the same temperature, will contain an equal amount, whether that space have been a vaccuum, air or any gas or mixture of gases. The rapidity of evaporation is increased by heat, diminution of pressure, greater extent of surface, and by currents of fresher air. When a given space will take up no more vapour it is said to be saturated, or the vapour to be at its maximum tension. Absolute humidity is the amount by weight of vapour in the air (say grains in a cubic foot); relative humidity or dampness, the approach of the vapour to condensation or maximum tension. The relative humidity only, concerns this discussion. It is measured by instruments called hygrometers or psychrometers, and varies with the temperature and other meteorological causes. A look at the daily reports of the U. S. Signal Service will show this. Saturation is termed one hundred; it is often reached in our climate. The lowest point on the scale is 0, but does not indicate absolute dryness. The dew point is the temperature at which moisture deposits on a cooled surface, and is higher as the relative humidity increases.*

The subject of the moisture of heated rooms has been much discussed, and is yet unsettled. Taking one-half saturation as a standard, it is found that a cubic foot of air saturated at 32° warmed to 70° would require the addition of 5.86 grains of water to be added to maintain its moisture at that standard. This may be supplied artificially by an evaporator in front of the warm air register or on top of the stove. Those attached to cellar heaters, being left in

* The following table shows the absolute humidity of saturated air at different temperatures (grains in a cubic foot, degrees F.).

0°	.545	60°	5.746
20°	1.298	80°	10 949
40°	2.862	100°	19.790

Hence a cubic foot of saturated air at 100° would, if cooled to 0°, deposit 19.243 grains of water. Conversely, if the temperature be raised from 0° F. to 100° F., 19.245 grains would have to be supplied to produce saturation.

the charge of servants, are rarely kept filled. Some moisture comes from the bodies of the inhabitants, steam from the kitchen and laundry, from plants kept in rooms and often watered, and a large proportion through walls. An ordinary brick will absorb $\frac{1}{10}$ of its weight of water; walls exposed to the beating of storms become damp on the inside from the water soaking through. This is remedied by coating the wall with boards or tin, or by planting clinging vines against it. These ward off the rain, and by the absorbing power of their tendrils draw moisture from the porous wall. This is contrary to vulgar prejudice, but is true. Excessive dampness existing in rooms can only be remedied by raising the temperature.

The influence of moisture on the health is yet a matter of discussion. In the out-door air dampness produces languor in warm seasons, and chilliness in cold, independent of the state of the thermometer. A dry air at 95° with a breeze is more bearable than a saturated air at 80°. So a moist atmosphere at 40° is more trying than a still air at or some degrees below 0°. We find that people who inhabit climates where it rains almost every day, as in some parts of Scotland and Ireland, and those in rainless districts where the moisture cannot be detected by the hygrometer, enjoy good health under similar surroundings in other respects.

Even in houses we have men employed as shampooers in Russian and Turkish baths, in dye-houses, and other manufactories, living for several hours daily in a hot saturated atmosphere without injury. In artificially heated rooms the dried air causes discomfort, which cannot accord with good health. This is less marked when the heat is from steam or hot water circulating in wrought-iron pipes. The artificially dry air from stoves and heaters contains products of combustion which have escaped as before pointed out. This fact will, in part, account for the difference.

Dampness of cellars and houses, and between decks of ships, is known to develop scrofula, rheumatism, phthisis, and to promote the spread of contagious and epidemic diseases.

This has been accounted for by the supposition that the dampness favors the spread of the virus or assumed germs of disease, as it does the perfume of flowers, or the stench of drains.

We really know little about it, except the facts stated.

Disinfectants.—These are supposed to act (1) by preventing fermentation and putrefaction, which favor the spread of diseases in some undetermined way. (2) By destroying or suspending the cause, as yet unknown, of disease. We have also *deodourisers*, which have a limited use in disguising noxious odours. In all cases where possible the offensive matter must be removed by ventilation, thorough cleanliness, and other measures already mentioned.

(1) The progress of decay requires the presence of air and moisture, with a temperature between the freezing and boiling points of water. Hence the known preservative effects of dry hot air, as seen in dried fruits and meats, and of those excluded from the air (canning). In polar climates flesh of animals has been preserved for centuries, and refrigerator cars and ships are used for transportation of fresh meats over thousand of miles.

A temperature of from 150° F. to 240° F. seems absolutely to disinfect clothing, dwellings, hospital wards, shipping, etc. It is supposed to act by destroying the unknown germs of contagion, infection, and miasm. A temperature below freezing *suspends* miasmatic poisons, as yellow fever, cholera, intermittents, etc., but cannot be said to destroy them.

The chemical disinfectants act by destroying organic matter whether fixed or aërial, by preventing decomposition and collaterally by removing offensive smells. The most important may be named, as follows: Creasote and the nearly identical carbolic acid, which coagulate albumen and destroy the low forms of organism (bacteria, vibrios, etc.), which, if not the cause of fermentation and putrefaction, accompany it. Being volatile, they also act on the contaminated air. Permanganate of potassa, *potassium permanganate*, KO, Mn_2O_7 [$K_2Mn_2O_8$] alone, or more rapidly on the addition of dilute mineral acids, gives off oxygen as ozone, and thus destroys both fixed and aërial organic matter. It is very efficient but somewhat costly, not so much so, however, as to interfere with its use in the ordinary household. Chlorine and sulphurous acid (*sulphur dioxide*), the former obtained from ordinary chloride of lime mixed with water, or more rapidly by the addition of an acid, the latter by burning sulphur, are especially adapted to use in unfurnished and untenanted rooms. The walls and ceilings should be previously thoroughly scraped, and afterwards whitewashed. Both gases are irrespirable when concentrated, and injurious to furniture. Chlorinated soda (Labarraque's solution) is more permanent and manageable than the corresponding lime salt, and may be used in lotions, etc. They act by removing hydrogen. The sulphurous acid is cheaper than Cl, and less destructive to metals exposed to it. One pound and a half of sulphur, burned with suitable precautions against fire, suffices for one thousand cubic feet of air, the windows and doors being kept closed. Bromine and iodine are expensive and possess no advantage over potassium permanganate.

Hyponitric acid, NO_4, (*nitrogen peroxide,* N_2O_4) is a powerful *oxidizing* agent, but is not now much used. It is made by the action of strong nitric acid on copper turnings. It cannot be used in furnished or inhabited rooms.

Of the non-volatile disinfectants may be mentioned ferrous sulphate, FeO,SO_3 [$FeSO_4$], *copperas, green vitriol.* It is very cheap and efficient, and is one of the best materials (preferably mixed with its weight of lime) for deodourising privies and drains. It acts in two ways: (1) By absorbing sulphuretted hydrogen. (2) By oxidizing organic matter. The iron absorbs oxygen from the air, becoming sesquioxide, Fe_2O_3, which is reduced by the organic matter to the protoxide, FeO, the organic matter being partially consumed by the oxygen given off. The protoxide again absorbs oxygen from the air, and thus the process is continuous. This action is seen in ordinary iron mould, which if not removed is soon found to eat a hole through the fabric. The salt should be used freely.

Charcoal, in coarse powder, absorbs both fixed and volatile organic matter, and by its power of absorbing and condensing oxygen in its pores rapidly consumes it. It is used in respirators, on perforated trays in ventilators of sewers, foul wells, and earth closets. It should be dry and freshly burned. *Dry earth* acts like charcoal, and when containing clay by the alumina present. The earth closet has come largely into use where water closets are not attainable. It has given general satisfaction. *Lime* has been already alluded to. Freshly slaked it is caustic, and destroys organic matter. As whitewash it is invaluable. For sanitary purposes *simple* slaked lime should be used.

Alumina compounds (sulphate, chloride) are fixed, and not adapted to aërial poisons. Otherwise they act like creasote and carbolic acid by coagulating putrescible matter, and are cheap and useful local applications. The sulphate in solution is valuable in cleansing the hands after post-mortem examinations or offensive surgical operations. Both are themselves inodorous.

Others of less importance may be named, sulphate of copper, chloride of zinc (Burnett's solution), used in embalming and in the preservation of timber; also corrosive sublimate, used for the same purposes. These act by their coagulating power. Nitrate of lead (Ledoyen's solution) is rather a deodouriser than a disinfectant. It is inodorous. Others not named are seldom used. The so-called disinfectants sold under proprietary names are costly and no better than those heretofore considered. The market price, which fluctuates, may be given as follows for the crude products, which answer every purpose for ordinary use: Carbolic acid (commercial creasote), 70 cts. a lb. Permanganate of potassa, 80 cts. a lb. Chloride of lime, 5 cts. a lb. Labarraque's solution, 6 cts. a lb. Copperas, 5 cts. a lb. Sulphate of alumina, 25 cts. a lb. Sulphate of copper, 9 cts. a lb. Corrosive sublimate, 60 cts. a lb. Nitrate of lead solution, 10 cts. a lb.

Deodourisers.—These act by disguising offensive odours, and in some cases at the same time give off ozone, as tar fumigations, turpentine, eucalyptus, and some other volatile oils. In all cases their use is only to be recommended where cleanliness and ventilation have been thoroughly used. Pastilles of fragrant gums, candles of myrtle wax, fumes of burned sugar, of roasted coffee, of vinegar, camphor, etc., are familiar. They may act usefully, by preventing the disgust and nausea due to the bad smell, and morally by the reassurance afforded to the timid during epidemics by the belief in their virtue. The metallic salts generally absorb sulphuretted hydrogen, one of the constant constituents of offensive odours, and are thus useful as deodourisers.

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